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An expert examination of the Ecological Footprint

Extract from final report

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Director of publication: Bruno Trégouët

Editor in Chief: Michel David

Authors: Michel David, Cécile Dormoy, Emmanuel Haye, Bruno Trégouët

Editor: Corinne Boitard

Translator: Geoffrey Bird

Design-Layout: Chromatiques Editions

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Political demand for use of the ecological footprint

France's *Grenelle de l'environnement* (environmental round table) meetings underscored the necessity for environmental and sustainable development indicators as a complement to gross domestic product (GDP). The ecological footprint was one of the indicators evoked by the working group '*Promouvoir des modes de développement écologiques, favorables à la compétitivité et à l'emploi'* (working group for the promotion of environmentally friendly development favourable to competition and employment). Within the framework of the *Grenelle 1* Act, the French government has stated its aim of establishing indicators for its National Sustainable Development Strategy (NSDS) and of developing new indicators that take account of environmental public goods in national accounting. The NSDS is currently being reviewed: the different departments of government will propose sustainable development indicators for the new strategy.

Following on from the debates surrounding this indicator, and especially during examination of the draft bill for the *Grenelle de l'environnement* framework law by parliament, on 20 January 2009, the prime minister requested the *Conseil économique, social et environnemental* (CESE – economic, social and environmental council) to consider use of the ecological footprint (EF) as an indicator of sustainable development that would send out clear signals to foster sustainable behaviour.
The CESE's report, issued in May, addresses the more general question of sustainable development indicators along with the EF itself. The CESE recommends use of scoreboards comprising several indicators rather than dissemination of composite indicators until these have become sufficiently robust.

At the same time, sustainable development and the environment were issues addressed by the 'Stiglitz' Commission, set up by France's President. The Commission's report proposes different types of approaches including indicators of excessive pressure on the environment. It emphasises the necessity for distinguishing between the wellbeing of present and future generations.
Overall, the EF has been the subject of numerous expert examinations and analyses. The study conducted by the *Commissariat général au développement durable - Service de l'observation et des statistiques* (CGDD–SOeS – general commissariat for sustainable development – Department for Observation and Statistics) of the *ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer* (MEEDDM – ministry for Ecology, Energy, Sustainable Development and the Sea) aims to provide elements arguing either in favour of adopting the EF or rejecting it, on the basis of scientific criteria.

Presentation of the ecological footprint

For a detailed presentation of the modes of calculation used, refer to the *Expert examination by SOeS* section, which explains the basis of the concept and gives some quantified examples.

Background

The ecological footprint concept was developed in the early 1990s by William Rees and Mathis Wackernagel, in a dissertation for a PhD in urban planning (Mathis Wackernagel defended his thesis in 1994 at the University of Vancouver under William Rees' supervision).

They then co-authored *Our Ecological Footprint, Reducing Human Impact on the Earth*, published by New Society Press in 1996. The EF is 'a measure of the load a given population places on nature. It represents the land area required to support that population's current levels of consumption of resources and absorb its waste.' The authors sought to develop a method to quantify ecological sustainability physically, proposing information more or less equivalent to that provided by certain monetary indicators such as GDP in the field of economics[1].

National EF accounts are now developed by the Global Footprint Network (GFN), of which Mathis Wackernagel is President. The GFN in a not-for-profit organisation set up in 2003 to develop and coordinate research on the EF. It currently works with more than 100 partner organisations including the WWF, which regularly includes national EF accounts in its 'Living Planet' reports. One of GFN's targets is for 10 countries to officially adopt the EF in the same way as they use GDP, by 2015.

Definitions and principles of calculation

'The Ecological Footprint measures the amount of biologically productive land and water area required to produce the resources an individual, population or activity consumes and to absorb the waste it generates, given prevailing technology and resource management. This area is expressed as global hectares, hectares with world-average biological productivity.'(WWF, Living Planet Report, 2008).

The EF concept attempts to answer the following question: does the human economy use more resources or services from nature than nature is capable of generating?

The EF was therefore conceived as a double entry accounting system:

- the amount of resources or services taken from the biosphere that are necessary for the human economy to function (demand); this represents the actual 'footprint';
- the amount of services the biosphere is able to regenerate (supply), referred to as 'biocapacity'.

Several hypotheses need to be assumed to construct the indicator:

- the central hypothesis underlying the EF is that the amount of renewable resources used is directly linked to the bioproductive area required to regenerate the resources and to absorb wastes produced by human activities[2]. In other words, each type of consumption or CO_2 emission can be evaluated in the form of a bioproductive area required to provide this service;

[1] Aurélien Boutaud and Natacha Gondran, 2009. « *L'empreinte écologique* ».

[2] To date, only CO_2 emissions are included in the calculations.

- to allow them to be aggregated, the different bioproductive areas are expressed in terms of world-average biological productivity, referred to as global hectares;
- the services provided by nature (resources, capacity to absorb waste) are only counted once for a given land or sea area, to avoid double counting; an area can only be assigned one function;
- the EF measures a country's net consumption, (domestic production + imports - exports), that is to say its final demand; the EF is attributed to the country consuming a good or service, regardless of its origin, and not to the producer; in this way the EF accounts for the amount of CO_2 emitted to produce imported or exported goods as well as embodied resources;
- EF and biocapacity can be compared: when demand is greater than supply the over-exploitation is referred to as the 'ecological deficit' or 'overshoot'.

On the demand side, the EF breaks down as follows:

- footprint arising from the consumption of natural resources (produce of agriculture, livestock farming, wood industry and fishing);
- footprint relating to built-up land areas;
- footprint arising from energy consumption, known as the carbon footprint.

The method of calculation of the EF differs for each category:

- the common basis for renewable resources consists, for each category of production, in dividing the amount of resources consumed (in tonnes per year) by the world-average yield (in tonnes per ha per year), followed by adjustment of this figure by the corresponding equivalence factor (into global hectares per hectare);

$$EF = \frac{\text{amount consumed}}{\text{world - average yield}} \times \text{equivalence factor}$$

- based on the assumption that built-up areas are expanding primarily over fertile areas, the EF for built-up areas views these areas in terms of the productivity of the agricultural lands they replace. This footprint includes consumption of hydroelectricity: the land area taken into account corresponds to the area occupied by the dam and the reservoir. As the areas of reservoirs are not known, they are estimated from the amount of hydroelectricity generated;
- for measurement of the ecological footprint of fossil energy consumption, the method consists in evaluating the area of forest required to sink the CO_2 emitted by the combustion of fossil energy during the manufacture and transport of goods consumed.

Where supply is concerned: biocapacity is defined as a country's biologically productive area. It is calculated for five types of land use: cropland, grazing land, forest, fishing ground (maritime and freshwater)and built-up land.
Comment: to avoid double counting there is no biocapacity calculation for energy. The forest serving to 'sink' the carbon is already taken into account in meeting the needs of the wood industry.

The method for calculation of biocapacity consists in multiplying the area for each type of use (crops, grazing, forest, fishing grounds) by a yield factor (national yield/world yield) then adjusting this figure by the corresponding equivalence factor.

$$\text{Biocapacity} = \text{area used} \times \text{yield factor} \times \text{equivalence factor}$$

The yield factor used differs depending on the category:

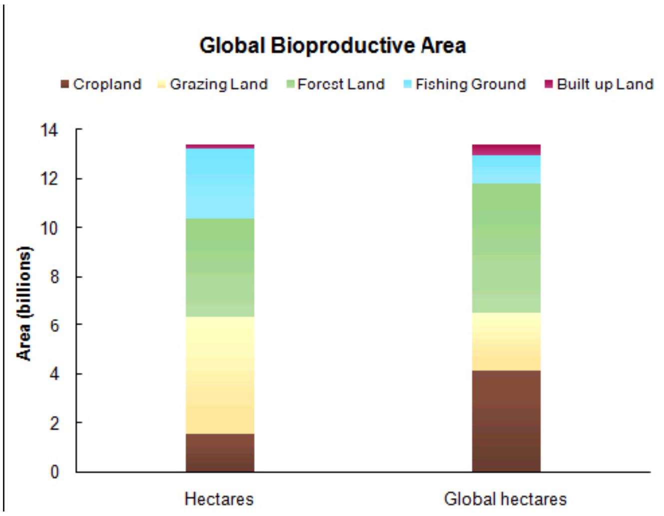
- for croplands, it is the ratio between national and world yields applied to each primary product;

- for grazing lands, it is the ratio of national yield to world yield that is used, production being expressed as weight of dry matter[3];
- for maritime fishing, it is the ratio between the yield per hectare of France's continental shelf and world continental shelf (in kilograms of biomass per hectare); for freshwater fishing the factor used is equal to 1;
- for built-up areas, the assumption that they encroach systematically on agricultural lands leads to use of the croplands yield factor;
- for forests, it is the ratio between national and world yields for production of logs (felled trees before any conversion process).

Conversion factors are used in calculating the ecological footprint: yield factor and equivalence factor

Yield factors are used to convert tonnes produced (e.g. agricultural produce, CO_2 emissions, etc.) into hectares. This conversion to surface area makes it possible to compare data that are not directly comparable. The principle underlying the calculation of these factors is that of a world-average yield. This world-average figure is then applied to national production for conversion into surface area.
Variants are distinguished, however, depending on the partial footprints in question. For example, the yield factor for the partial carbon footprint is the rate of uptake of CO_2 per hectare of forest.

The equivalence factors are in fact a weighting system for the different types of land (croplands, forests, grazing lands, etc.) in accordance with their potential agricultural productivity, estimated with the FAO's Global Agro-Ecological Zones (GAEZ) model. The areas calculated in this way are measured in global hectares. By construction, at world level, the total number of global hectares is equal to the total number of real hectares.
NB: Equivalence factors are only used when aggregating different types of areas.



Source: GFN.

[3] *GFN uses a per hectare yield for French grazing lands of 13.1 tonnes of dry matter, compared to a world average yield of 6.2 tonnes (constant value between 1961 and 2005).*

Scope of the ecological footprint

The GFN's approach focuses on the question raised by the EF: what natural resources do we have and how much of them do we use?

The EF's scope is therefore limited to the regenerative and biological parts of the ecosystem, in other words, essentially, the biosphere. Elements of natural capital that cannot be regenerated, either directly or indirectly, by photosynthesis are therefore, by definition, beyond its scope. This is the case, for example, for resources extracted from the earth and freshwater abstraction (Boutaud and Gondran, 2009).

In the current version of *National Footprint Accounts* (GFN), the term 'waste' refers only to CO_2 emissions arising from the use of energy produced by burning fossil fuels (coal, oil and natural gas).

Moreover, the EF does not describe the intensity of land use, biodiversity losses nor activities or phenomena (such as discharges of pollutants or soil erosion) that pose a long-term threat to the capacity of an area to continue to provide ecological services. However, the EF's designers do indicate that degradation of soils and of other parts of the environment will, over time, lead to a reduction in productive areas, and therefore of biocapacity.

Lastly, by limiting its scope to the ecological aspects of sustainability, the EF gives no direct information on human wellbeing.

Development of the method

Compound based and component based approaches: the initial EF calculations at national level used a component based approach making use of life cycle analysis (LCA) studies. However, owing to the lack of exhaustive information on product life cycles and problems of double counting, GFN now uses a compound based approach for national calculations. This method uses aggregated national data.

Nuclear energy was included in the EF calculation in the same way as fossil energy until 2008. It has been excluded since 2009.

The special case of nuclear energy

'After extensive discussions and consultations, Global Footprint Network's National Accounts Committee recommended eliminating the nuclear land component from the National Footprint Accounts in order to increase their scientific consistency. This change has been implemented in the 2008 edition of the National Footprint Accounts. The National Accounts Committee concluded that the emissions proxy approach for calculating the footprint was not scientifically sound because:

1. There is no scientific basis for assuming parity between the carbon footprint of fossil-fuel electricity and demands associated with nuclear electricity.
2. The primary concerns related to nuclear electricity are often cited as costs and undue subsidies, future waste storage, the risk of plant accidents, weapons proliferation and other security risks. Ecological Footprint accounts are designed to be historical rather than predictive, and thus consideration of potential future impacts on biocapacity [*radioactive waste*] should not be included. [...] In the National Footprint Accounts for the year 2003, the nuclear footprint represented approximately 4 per cent of humanity's total footprint.

However, for countries with significant nuclear power supply such as Belgium, Finland, France, Japan, Sweden and Switzerland, the method change influences their national footprint values to a greater extent.'

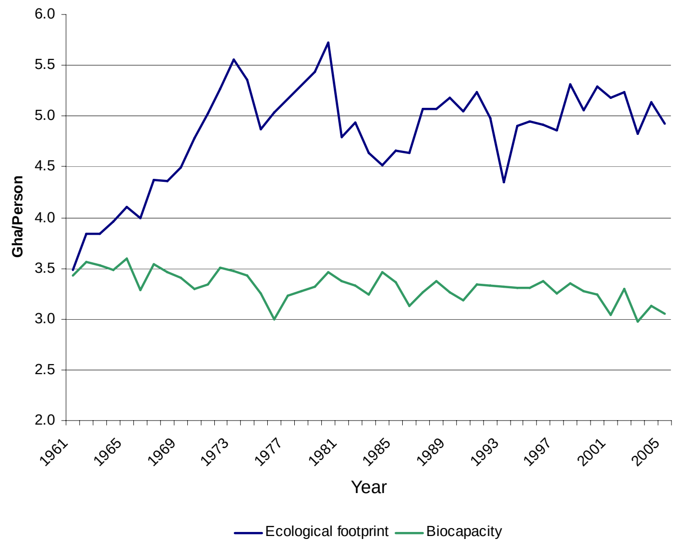
Source: Living Planet Report, 2008.

Research (GFN and the scientific community): the GFN is concerned to improve the quality of the data and methods used. To achieve this, it relies on two expert committees (the national Accounts Review Committee and the Standards Committee). Country partnerships also contribute to evolution of the footprint methodology. In 2007, the GFN and its scientific partners established a research programme to improve the accounting methodology. Priorities include better estimation of the footprint of trade flows, combining several methods (product LCAs, input-output analysis) and including an estimate of the service sector's EF.

Evolution of France's EF and biocapacity

Between 1961 and 2005, France's EF increased by 85 per cent, from 160 million global hectares (Mgha) to 300 Mgha. However, two periods of sharp reduction are observed at the start of the 1980s and 1990s. Biocapacity fluctuates widely over the period, going from 158 Mgha in 1961 to 184 Mgha in 2005, an increase of 13 per cent.
The evolution is more or less the same for the per capita footprint with, however, relative stabilisation of the footprint at around 5 gha per person since the mid-1970s, to be compared with a per capita biocapacity slightly above 3 gha.

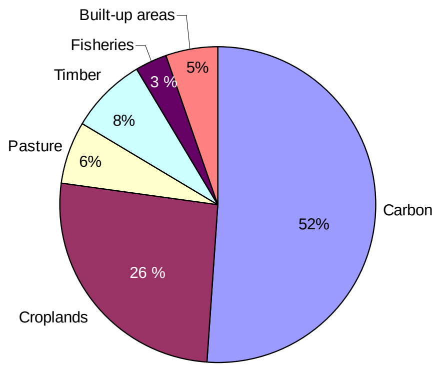
Changes in France's per capita ecological footprint and biocapacity



Source: GFN.

The share of energy in the EF increases more and more. Make-up of the EF has gone from 50 per cent agriculture in 1961 to 50 per cent energy in 2005.

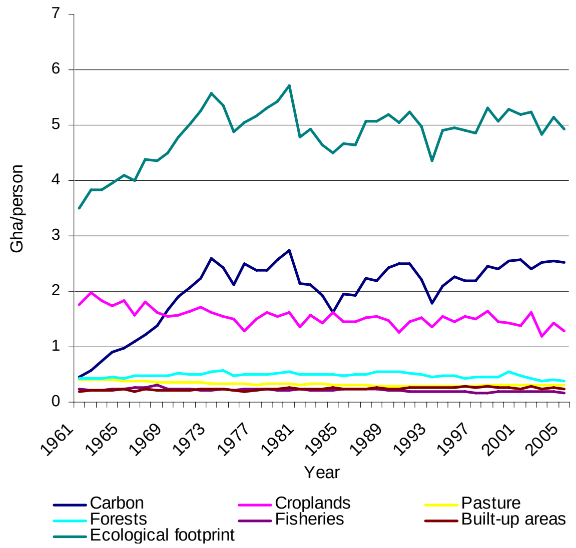
Components of France's ecological footprint in 2005



Source : GFN.

The overall EF is mostly the result of the partial carbon and cropland footprints. Variations in the overall EF result, mainly, from annual variations and major trends in the carbon footprint. Furthermore, they are also impacted by a trend towards a lower cropland footprint, with the exception of some specific years.

Evolution of the components of France's ecological footrpint between 1961 and 2005



Source : GFN.

Expert examination by the *Service de l'observation et des statistiques* of the *Commissariat général au Développement durable*

The approach

On 25 June 2007, the agenda of the meeting of the *Conseil scientifique de l'Institut français de l'environnement* (scientific council of the French institute for the environment – Ifen) focused on overall indicators for environment and sustainable development. In response to wishes expressed at the meeting, Ifen (which had by then become SOeS) incorporated expert examination of the EF concept applied to France into its work programme. The study was to include analysis of the concepts underlying the method and the tools and sources used, so as to identify the benefits, limitations and usages that can be made of the EF. The following criteria were considered:

- transparency and measurability: determining factors for the scientific basis and reproducibility of the approach; Ifen therefore wished to obtain the calculation algorithm to be able use GFN's compound method based on the latest standard hypotheses;
- robustness and comparability: criteria that can be ascertained by evaluating the effects of the hypotheses applied, hence the decision to quantify several alternative scenarios.

The SOes' examination comprised two phases:

Phase 1 – standard calculation

The first step was to undertake a standard quantification of the footprint using the 'compound' method, based on the algorithms and data provided by GFN. The aim was to understand the method and be able to reproduce it, in order to:

- assess the transparency of the EF methodology;
- reach a conclusion as to the reproducibility of the calculations.

To do this, SOeS sought to identify the data sources and conversion constants used by GFN, analyse the calculation chain and, lastly, compare results.

The algorithm for calculation of the EF was converted into a user-adjustable computer programme. This made quantification of the impact of the alternative hypotheses easier and more reliable.

Phase 2 – testing the impact of alternative hypotheses

The aim of this test phase was to produce alternative quantification and to measure any differences in relation to the standard quantification. Sensitivity of the results to the following changes was tested during this phase:

- use of other data sets: data from national or updated databases;
- impact of reductions on GHG emissions to 2020 or 2050;
- new hypotheses as to the coefficients: carbon absorption and notion of sustainable agricultural yield.

A Monitoring Committee was set up to assist SOeS throughout the study and to help in understanding the strengths and weaknesses of the EF, and to choose the sets of alternative hypotheses to be tested.

The SOeS carried out a standard quantification of the footprint using the algorithms and data provided by GFN. A contract was made with GFN for provision of data and algorithms (2008 issue of National Footprint Accounts for France, 1961-2005 series).

The criteria used for evaluation

Reproducibility and transparency were the prime criteria retained by SOeS to start evaluation of the ecological footprint. Given the abundance of the available literature on the EF, the decision was made to not immediately address the concept. However, examination of the criteria adopted necessarily touches on the conceptual basis of the indicator, as it raises questions as to its robustness, comparability and relevance.
The approach adopted is based on that of epistemologists[4], for whom the scientific nature of a statement is evaluated by the possibilities for its being refuted. In concrete terms, these authors consider that transparency is indispensable to identify what, in the approach adopted, arises more from ideology, apriorism or metaphysics than from scientific logic.

From a more pragmatic standpoint, looking in detail at the calculations allows an appreciation of the robustness of the indicator, whether in terms of the concepts, data or calculation algorithms.
From the conceptual point of view, the work carried out by the SOeS re-emphasises certain choices the consequences of which tend to be overlooked, even though they have a direct impact on the relevance of the indicators and on the conditions of their use. This is the case, for example, for the hypothesis of the absence of biocapacity regarding the carbon footprint. The desire to avoid double counting explains the footprint designers' choice, given that a forest area cannot be used both as a source of materials and fuel for heating and simultaneously act as a carbon sink. This position –the subject of debate within the Monitoring Committee– has important consequences for the size of the footprint and for the resulting more or less optimistic interpretation of it.

Detailed examination of the information used also makes it possible to address the issue of robustness of the indicator from the point of view of its sensitivity to sources, to the recentness of data and to the hypotheses underlying some of the constants. This is essential to be able to decide on comparability over time and between countries. Thus, the erratic nature of changes in the EF raises the question of the relevance of the indicator when drawing up an interpretable diagnostic analysis. This justified the conducting of an in-depth examination of the statistical data over time.

Transparency and reproducibility also made it possible to address robustness and relevance via the calculation algorithm.

In addition to the statistical work on reproduction of the calculations and on the temporal analysis of results, the SOeS carried out a multi-dimensional analysis aiming to situate the EF in relation to the European sustainable development indicators.
The aim was, notably, to emphasise that the footprint does not cover all aspects of sustainable development—something which the designers recognise—and that other indicators provide additional information. This seemed worth pointing out since a bill has been placed before France's parliament proposing to make the footprint 'the key indicator of sustainable development'[5].

Results of the technical test

The results of the test are presented in detail in the technical report, only the main points of the EF test are given here.

NB: The test consisted of a study of the possibility of reproducing and standardising the calculations on the basis of the methodology and data provided by GFN. This approach nonetheless led to the formulation of questions, comments and reservations as to the methodology adopted.

Conclusions to phase 1: overall, reproducibility of the calculations is good. The origin of the statistics used is clearly identified and the data are from official and independent sources of statistiques (United Nations, International Energy Agency, etc.). Publication, for the fist time in 2008, of a detailed methodological guide represents a major effort on the part of GFN towards greater transparency. However, the origin of the conversion constants is not yet sufficiently explicit. Moreover, the methodology is evolving but changes in methods are little explained or not explained at all (with the exception of the exclusion of nuclear energy in the 2008 issue).

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[4] *See, in particular, the work of Karl Popper, but also the controversies with Imre Lakatos and Paul Feyerabend.*
[5] *Proposed bill aiming to reduce France's EF. Assemblée nationale n° 1369, 6 January 2009.*

Reproducibility

- Reproducibility of the EF calculations is good. The difference between the values from SOeS' calculations and those of the GFN is between -3.2 per cent and +0.5 per cent. The mean difference is -0.5 per cent and the median difference -0.2 per cent. Over the study period (1961–2005) the difference is greater before 1975 (mean difference of -1.5 per cent). The difference then stabilises, oscillating between -0.5 per cent and +0.5 per cent. After study of the components of the footprint the difference can be attributed to the 'crops' component. More precisely, it can be attributed to a problem of coherence between the conversion factors for head of cattle into tonnes of meat described in the guide and those used in the file.
- Reproducibility of calculations for biocapacity could not be tested under the same conditions: the source used here for estimation of different types of areas is the CORINE Land Cover (CLC[6]) database. The SOeS does not have the information for the different items of data used by GFN in its calculations. The wide differences doubtless arise from a different selection of items.

Transparency

- Publication, for the first time in 2008, of a detailed methodological guide represents a major effort on the part of GFN towards greater transparency.
- The design of the new spreadsheet and the methodological guide facilitated appropriation of the tool.
- The origin of the statistical data used is clearly identified and the data are from official sources of statistics (FAO, International Energy Agency, etc.). Some exceptions were noted, however: the sources used to estimate France's share of international transport (bunker fuel), and the share of unharvested cropland are not cited.
- The origin of conversion constants is not always sufficiently explicit: this is particularly true for embodied energy. It is also the case for certain yield factors (forests, pastures).
- The origin of some of the nomenclatures is not always sufficiently explicit (crops, cattle farming).
- The methodology is evolving. This is a positive point. However changes in methods sometimes lack adequate explanation. Until 2003, nuclear energy was included in the global footprint. In 2003, nuclear's footprint accounted for 25 per cent of France's total EF. In the 2008 issue of the accounts nuclear power is no longer included in the calculation but, for the same year, 2003, the footprint has reduced by only 14 per cent. The methodology must have changed for other components. In the 2008 issue, the croplands footprint for 2003 is much higher (+50%) than that given in the previous issue.

Robustness of the methodology

- The nomenclatures used are sometimes outdated (UN - 1976 whereas the current ones date from 2006). However, this is a result of the necessity of having full data sets for all countries.
- Some conversion rates are constant throughout the study period (energy, crops, forests, rate of extraction of secondary materials from primaries).
- The level of detail of data varies widely.
- Method of estimation: GFN uses CORINE Land Cover data to ascertain land use. However, these data are only available for 1990, 2000 and 2006. The missing data are estimated assuming that an increase in population results in a proportional increase in land use– an arguable method.
- The methodology and data from GFN are provided in the form of a computer system 'folder' to facilitate use by users who are not IT specialists, but the calculation sheets are extremely voluminous. SOeS's calculations were therefore performed on a computer deemed to be more suitable. They are reproducible and a trace is kept of the parameter settings used when testing alternative hypotheses in the data and conversion coefficients.

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[6] *Nomenclature CORINE Land Cover : http://www.ifen.fr, 'database' section > Land cover'.*

Conclusions to phase 2:

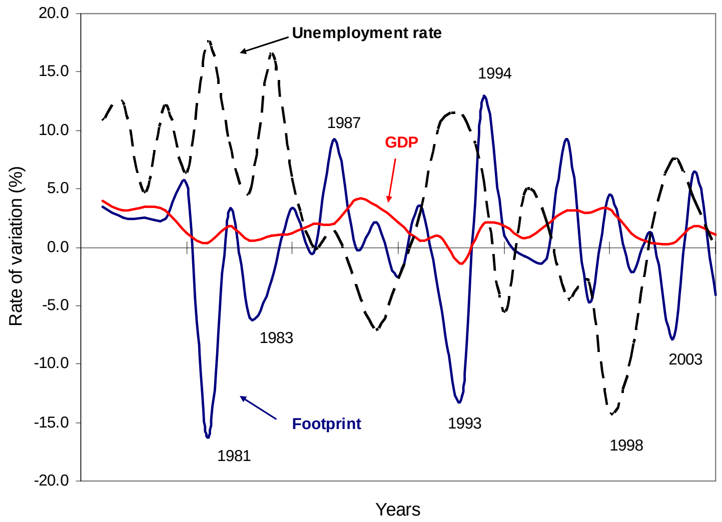
- Calculation of the partial carbon footprint from Customs data is satisfactorily reproducible on condition that correspondence is established between the nomenclatures.
- The nomenclature used by the GFN for agricultural produce has not been clearly identified, in spite of requests for further information by SOeS. As a result, the test remained too imprecise to provide interpretable results.
- Using a CO_2 sequestration rate of 3.89 tonnes per ha for the forest (IPCC), instead of 3.59 tonnes (GFN), gives a difference of 0.2 global hectares in terms of footprint, representing 4 per cent of the total footprint. This influence of conversion constants reinforces the necessity of clarifying the methodology for ascertaining embodied energy. It also justifies obtaining further information on the extraction rates used for secondary materials.
- The effects of a reduction in CO_2 emissions and of a switch to organic farming were also tested, 'other things being equal'. The exercise revealed the limits, and even the dangers, of a purely mechanical approach. Implementation of a systematic approach would be greatly facilitated by use of software allowing adjustment of the parameters of the footprint 'model'.

Comparability

The technical report showed that changes in the EF are sometimes erratic over time. Can these movements be attributed to the economic situation? Or do they reflect real but momentary changes in behaviour?
To attempt to answer these questions, which relate to the robustness and relevance of the indicator, a temporal analysis of the statistical data for the 1975-2005 period was conducted.

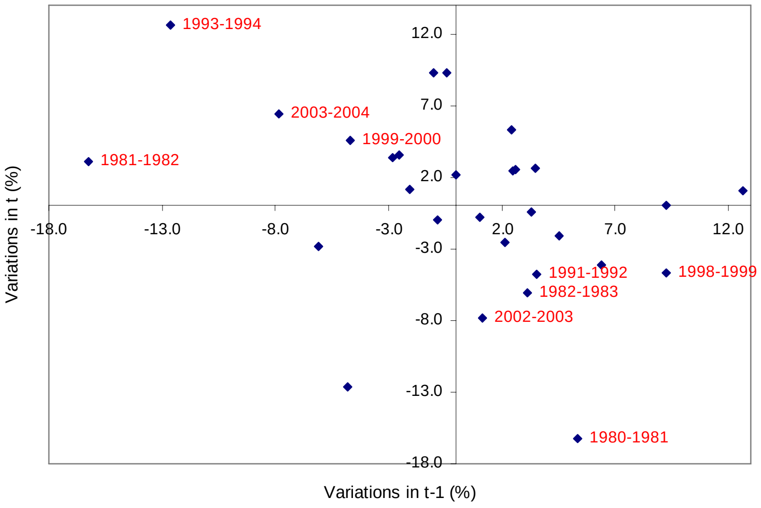
The footprint varies somewhat erratically from year to year, whereas the value of the indicator remained relatively stable in the 1975-2005 period: 4.9 gha/person in 1975, 5.1 at the halfway stage in 1990, and 4.9 again in 2005. Over thirty years, the absolute value of the rate of variation was over 5 per cent one time in three. Its absolute value exceeded 10 per cent in 1981 (-16.6 %), 1993 (-12.7 %) and 1994 (+ 12.6 %).
The graphs below illustrate these fluctuations.

The ecological footprint, showing wide annual fluctuations



Source: GFN, Insee ; SOeS processing.

The ecological footprint, irregular patterns



Note: On the graph, only pairs of years corresponding to a change in direction of variations are marked. For example, between 1981 and 1982, the rate of variation went from -16 per cent to +3 per cent. Between 1998 and 1999, it went from around +9 per cent to nearly -5 per cent.

Source: GFN, SOeS processing.

Findings from the analysis: The fluctuations in indicator values are difficult to interpret over the short term, rendering use of the indicator to shed light on public policy difficult.

Analysis of correlations

Years of great reduction correspond to economic low points, often marked by a net slowing in the rate of growth of per capita GDP and a sharp rise in the unemployment rate. For example, in 1993, the footprint reduced by 12.7 per cent, the per capita GDP by 1.4 per cent (+ 0.9 per cent in 1992) and unemployment rose by 1 point. Conversely, in 1994, the per capita GDP rose by 1.9 per cent and the rise in unemployment continued but at a rate that was halved in relation to the previous year. The footprint then increased by 12.6 per cent.

Globally, the coefficient for the linear correlation between the rate of variation of the footprint and that of GDP (+ 0.52) reflects a significant linear relationship[7] between the two series. The relationship between the variations in the footprint and unemployment rate is barely significant, in spite of some momentary changes in the same direction.

The graph below is a reconstruction[8] of variations in the footprint from variations in the per capita GDP. The differences between the estimates, in red, and observations, in blue, give an idea of the variations in the footprint not attributable to the economic context.

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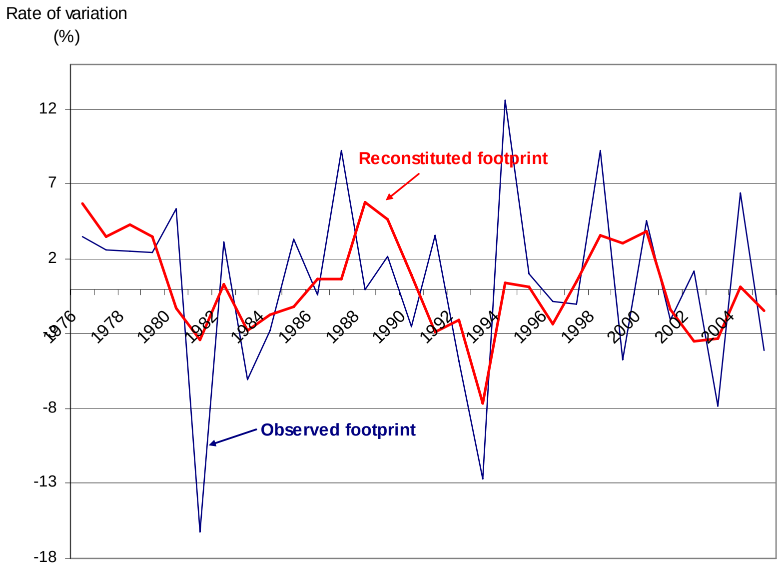
[7] With 3.2 per cent risk of rejection of this hypothesis (See. T-Student de la régression).

[8] With the model: $VEE^{i}_{t,t-1} = \alpha\, VPIB^{i}_{t,t-1} + \beta + \varepsilon_{t,t-1}$ *where* VEE *and* $VPIB$ *represent the annual rates of variation between t and t-1 in the footprint and GDP.*

Impacts of variations in GDP on those in the footprint



Source: GFN, SOeS processing.

Findings from the analysis: in spite of the time lag and the difference in amplitude between the series, the correlation between variations in the footprint and in GDP can be perceived visually. Beyond that, is it possible to interpret the differences between series reconstituted from GDP and observed series as being the reflection of changes in the pressures from human activities once the effect of the economic context is eliminated? This is a difficult question to answer. The amplitude of turn arounds and the differences they can generate between series seem, *a priori*, too great to be interpreted as changes in behaviour.

Analysis of components

With the exception of years 2003 and 2004, it is the carbon footprint that contributes[9] on average around 60 per cent of the overall variations in the footprint. Conversely, in 2003 and 2004, it is the croplands footprint that is responsible for most of the overall variation. Once again, the link between the economic situation and the climate is found. In periods of slowed activity, energy consumption reduces and the footprint shrinks. In 2003, crop production reduced due to a drought and the footprint diminished, world agricultural yields used for the calculations remaining fairly stable that year.
The footprint for built-up areas contributes little to the fluctuations in the footprint in the years of wide fluctuations in the indicator. However, the sharp variations in this component are surprising, with annual variations of over 10 per cent in absolute value terms one time in five. Based on data from CORINE Land Cover, built-up areas in France are estimated to have increased by only 3 per cent between 2000 and 2006. Moreover, given its relative low weight, consumption of hydroelectricity has had only a limited impact on the built-up area component. In fact, it is the variations in the cropland yield factor that cause the movements in the footprint attributed to built-up areas.

Findings from the analysis: the impact of the built-up areas component is so low, and its variations so volatile, that the question arises as to whether it is reasonable to include it in the calculations.

[9] *Contribution of a component i is calculated as follows:* $C^i_{t,t-1} = \dfrac{V^i_{t,t-1}}{\left|V_{t,t-1}\right|}$ *where* $VEE_{t,t-1} = \sum_i VEE^i_{t,t-1}$

Additional work by the SOeS

On 9 January 2009, Ms Martine Billard, Mr Yves Cochet, Mr Noël Mamère and Mr François de Rugy proposed a draft bill for Law n° 1369 of which the first article stipulates that: 'the ecological footprint shall constitute the instrument of evaluation of policies implemented to combat climate change and preserve life on Earth'.

To contribute to the debate, the SOeS proposed a brief statistical study to position the EF at the European level, alongside other indicators.

The analysis illustrates the fact that, in spite of its coherence with some sustainable development indicators (SDI) and its specific contribution, the EF cannot on its own reflect all of the economic, social and environmental issues surrounding sustainable development. It also shows that other environmental indicators also carry information specifically relevant to 'evaluation of policies implemented to combat climate change and preserve life on Earth'. Moreover, the designers of the EF have never claimed it to be the sole indicator of sustainable development. However, it seemed necessary to point this out in response to the proposed law aiming to reduce France's EF[10].

The data studied concern 23[11] of the 27 countries of the European Union and relate to the following European indicators of sustainable development, adopted on the basis of their availability for a maximum number of European countries:

European indicators used for the analysis

Level	Indicator	Abbreviation
1	Greenhouse gas emissions	GHG
1	Share of renewables in gross inland energy consumption	Sren
1	Growth rate of real GDP per capita	GrpcGDP
1	At-risk-of-poverty rate (after social transfers)	Rpov
3	Life expectancy at age 65 for males	LeM65
2	Electricity consumption of households	C elhs
2	Municipal waste generated	Waste
2	General government consolidated gross debt as percentage of GDP	Debt
2	Government investment, % of GDP	govinv%GDP
2	Modal split of freight transport: share of railways in total inland freight in tonne-km	RIF
2	Total employment rate (persons aged 15 to 64)	Temp1564
2	Death rate due to chronic disease (for persons aged less than 65 years)	drCd
2	People killed in road accidents	Rdeaths
s	GDP per inhabitant	GDP/inhab
s	Ecological footprint	Footprint
s	Ecological balance	Eco bal

Technical indicators: Level 1 indicators correspond to 'lead objectives' associated with the European Sustainable Development Strategy (SDS), those at Level 2 to priority objectives and those at Level 3 to actions. 's' type indicators are not on the list of European SDIs; they are included because of their relevance for the analysis and are dealt with as additional elements in the factoral data analysis method.

Source: Eurostat, SOeS processing.

The on-line table with rows of the 23 countries and columns of these indicators was subject to multidimensional analysis of which the principle is presented in the box below.

[10] The draft bill for Law n° 1369 aiming to reduce France's EF, put before the Assemblée nationale (parliament) on 6 January. The first article of the bill is worded as follows: 'The aims and outcomes of policies implemented to combat climate change and adapt to it, to conserve biodiversity and services associated with it, to contribute to an environment that is not harmful to health and to preserve and value of landscapes are evaluated using the tool known as the 'ecological footprint'.
[11] Bulgaria, Cyprus, Malta and Romania were not included in the calculations due to missing data.

Analysis method

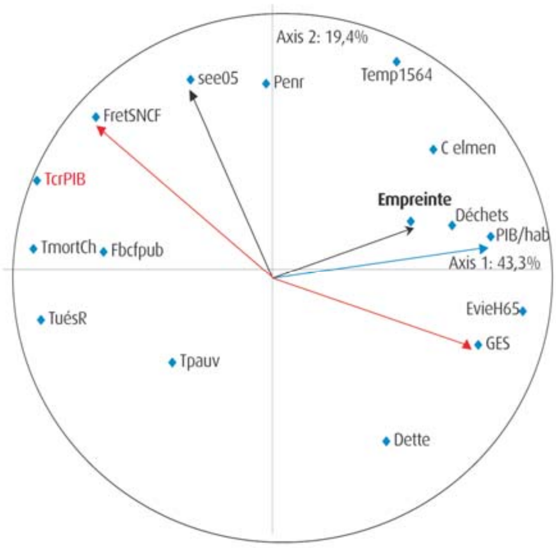
For factor analysis (FA), a large table of data is studied with columns that correspond to variables[12] and rows that contain observations. The general principle of the calculation algorithm is almost always the same, the methods only differing in terms of the initial mode of data transformation (metric and weighting).

A representation of the data that is simplified but not too distorted is sought by a presentation in the form of a map or set of maps.
The axes engendered by these maps have no *a priori* interpretation as they are synthetic: they correspond, in fact, to the best axes of inertia of the cluster corresponding to the initial table. They must therefore be interpreted by means of a technique which may differ from one method to another but which, in all cases, is based on mathematical aids for interpretation.
Multiple factor analysis (MFA) uses the general principles of FA, but offers greater possibilities for analysis when the table columns can be grouped into subsets of variables that are of interest for analysis. In the example in question, the subsets are the different aspects of sustainable development (economic, social, and environmental), each represented by several variables.
The method balances the role of groups when they are made up of numbers of different variables. It shows up the differences between partial clusters (each aspect of sustainable development) and the overall cluster.

The graphic below gives an approximate idea of the linear correlations between indicators. Its interpretation is relatively simple:

- vectors oriented in the same direction and forming an acute angle are indicators that correlate positively[13];
- vectors in opposing directions correspond to indicators that correlate negatively;
- vectors that are perpendicular correspond to indicators between which there is no linear correlation.

An anlysis of correlations between the EF and other sustainable development indicators



Source: GFN, Eurostat; SOeS processing.

The result showing correlation between the EF and per capita GDP is found here again.

More interesting, and more conclusive for the indicator, the footprint per person correlates with the SDIs indicating pressures from human activities exerted upon the environment. The footprint increases with amounts of waste from households. Although not

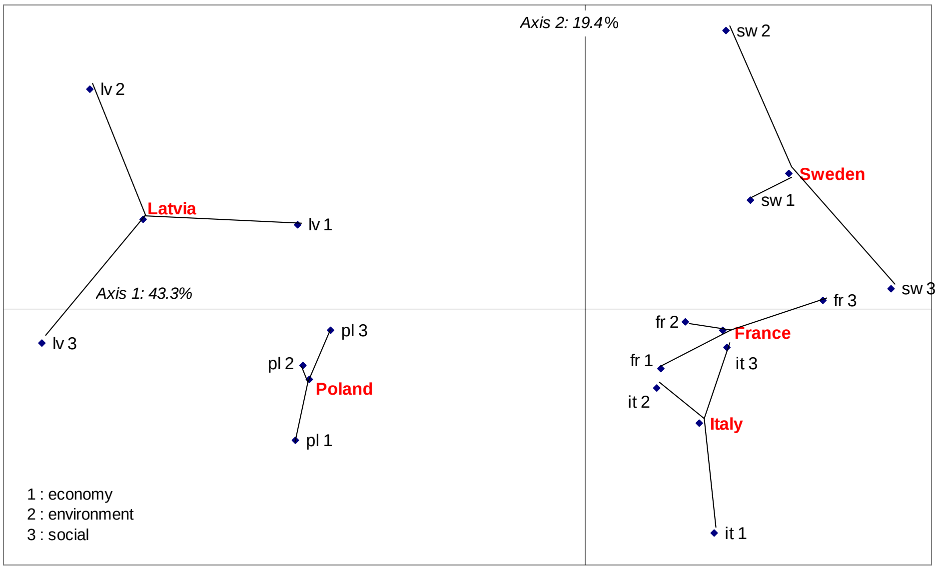
[12] *For correspondence analysis, the columns describe the modalities of a qualitative variable. For multiple correspondence analysis, the columns are the modalities of several qualitative variables.*
[13] *Mathematical aids for interpretation are also available to back up the analysis.*

quite so clear, the significant correlation[14] between household consumption of electricity and the EF is worthy of mention. This is also the case for GHGs[15].

Other results, however, concur less with expectations. Although no causal link must be assumed, the risk of poverty increases as the footprint reduces, and this is also the case for chronic mortality and road deaths. This negative correlation is simply the result of the fact that the countries in which these risks are high are somewhat lagging in terms of public health and social development or development of infrastructure, linked to a low level of economic development.

Furthermore, for all of the 23 countries covered, there appears to be no significant link between the indicator and the share of renewables in gross inland energy consumption.

Behaviour of several countries in relation to the three pillars of sustainable development



Source: GFN, Eurostat; SOeS processing.

Based on a few examples, the graph above is a reminder that the overall behaviour of a country where sustainable development is concerned –in terms of the indicators applied– is the resultant of partial forms of behaviour relating to each of the pillars: economic (code 1), social (3), and environmental (2). For example, France and Sweden are far closer in terms of the behaviour described by the social variables than for the environmental variables.

The last lesson to be drawn from this analysis relates to the linear correlation between the footprint and the ecological balance, meaning that all sorts of cases may exist, including:

- a small imprint in the European context and a negative ecological balance: this is the case for Poland and The Netherlands, given their low biodiversity;
- a large footprint and a positive ecological balance: this is observed for Finland and Sweden, countries with high biocapacity.

To better understand such situations, it must be borne in mind that the footprint is calculated from a consumption standpoint, meaning that a country's imports are included in its consumption. This arises from a concern to cover the global and inter-dependent aspects of sustainable development. In this way, the footprint of an industrialised country is not reduced by the country's recentering its activities around design while relocating its productive activities. The ecological deficit for a given country can therefore be large because of its foreign trade, whereas the state of its own environment may be well preserved or even improving. This choice must be firmly borne in mind when interpreting the footprint at national level.

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[14] In statistical terms, for 23 observations, the linear correlation coefficient must be greater than 0.3 to reject the risk of concluding incorrectly on a link between indicators (fixed at 5%).

[15] From a statistical standpoint, these correlations are more the reflection of colinearity, i.e. a link relating to the mode of calculation, than of causality.

Findings from the analysis: the EF alone cannot reflect all of the economic, social and environmental issues involved in sustainable development. Moreover, the footprint's designers make no such claim for their indicator.
The EF provides indications that are consistent with those from some environmental indicators and are complementary to others. Conversely, it sometimes appears to have no correlation with significant indicators such as share of renewables in gross inland energy consumption.
Lastly, the level of the footprint per person and the ecological balance must be analysed simultaneously given their characteristic lack of correlation.

Findings of the Study Monitoring Committee

Composition and role of Monitoring Committee

The Monitoring Committee was made up of members of GFN, civil servants, the scientific community, interested associative groups and experts (list of members given in Annex).
Its role was to assist the SOeS in ascertaining the strengths and weaknesses of the tool and additional methodological tests to be performed.

Discussions within the Monitoring Committee

Three meetings were held, in November 2007 and in April and July 2009.
Discussions covered the organisation of the study, technical aspects and the strengths and weaknesses of the EF.

Different expectations in terms of indicators

Differences appeared in the participants' levels of technical knowledge of the tool, notably due to their widely differing needs in terms of indicators. Some were seeking a means of raising awareness usable at the global level, others a tool suitable for orienting actions at the local level. In Belgium, for example, the study conducted by the *Bureau fédéral du Plan* (federal planning bureau) was intended to analyse the relevance of the footprint as an indicator of sustainable development; the study also aimed to identify links with national accounts and satellite environmental accounts.

Points of agreement and disagreement on the strengths and weaknesses of the EF

The EF's qualities form part of the areas of agreement between Monitoring Committee members:
- powerful tool for communication/awareness raising;
- original design;
- inclusion of relationships between countries and the world;
- fostering of a 'responsible consumer' attitude.

There was also agreement as to what the EF does not measure.

A major point of discussion and of disagreement was the definition of 'overshoot' or ecological deficit and the fact that the deficit is based mainly on excess CO_2 emissions.

At the global level, the ecological balance is, by construction, balanced for croplands, grazing lands and built-up areas. However, this does not mean that some imbalances –such as overgrazing, for example– do not exist locally. On the other hand, imbalance is possible for forests and fishing (deforestation, overfishing).
Where the 'carbon' footprint is concerned, the ecological balance is, by construction, negative. The carbon footprint is calculated as the area of forest needed to absorb the CO_2 emitted by human activities and not sequestered by the oceans. Now, in the presentation of the accounts (see table below), there is no specific biocapacity opposite: even if the forest simultaneously sinks carbon and produces timber, GFN has chosen to attribute only one function to each area. It considers that the timber removed will,

in the near or more distant future, emit its CO_2 to the atmosphere. The carbon footprint must therefore be viewed as a sort of fictional forest area, held in reserve, and whose only role is to sequester the excess carbon emitted today[16].

However, the carbon footprint represents around half of the EF (52 per cent for France). The consequence is that the ecological deficit measured by the footprint at the global level is essentially a reflection of excess CO_2 emissions.

France's EF, biocapacity and ecological balance for 2005

In gha per person

	EF	Biocapacity	Ecological balance
Croplands	1.28	1.55	0.27
Pastures	0.32	0.34	0.02
Forests	0.39	0.73	0.34
Fishing	0.17	0.17	0
'Carbon' footprint	2.52		**-2.52**
Built-up areas	0.25	0.25	0
Total	**4.93**	**3.05**	**-1.88**

Source: GFN.

WWF-France, Global Footprint Network and other expert members of the Monitoring Committee expressed an alternative point of view. They consider that the EF –with its methodology that sums all of the ecological services relating to use of produce from the soil and of absorption of carbon emissions and comparing this sum with total biocapacity– makes it possible to show up the GLOBAL overshoot. They explain this by the fact that natural areas are in competition for their use: a hectare of land used to grow potatoes is not available for urban development nor as an area of forest that could produce timber or absorb carbon. The relevance of this approach becomes clear when, for example, analysing the impact of agrifuels: an analysis limited to measurement of the carbon footprint of an agrifuel such as ethanol has a footprint that is smaller than that of gasoline. However, fuller analysis (carbon footprint + footprint of croplands used to produce the agrifuel) may be far greater than that for gasoline. Competition between land uses is a reality, as demonstrated by this example which illustrates the limits of agrifuels pointed out by more and more scientists.
WWF-France, GFN and other Monitoring Committee experts thus concluded that the EF shows up an ecological deficit that is not 'based essentially' on excess CO_2 emissions, as stated in the preceding point of view, but on a global overshoot (soils + carbon taken together) of the planet's natural carrying capacity.

It was underscored that the EF reasons in terms of present-day technologies when it uses, for example, conversion factors that remain constant throughout the study period.

How should the footprint be used?

This examination has, initially, allowed an explanation of the EF methodology. This has been a very useful phase, even though the indicator is considered, on the face of it, easy to understand by the general public. In fact, despite the publication of a methodological guide on the footprint published by the GFN in 2008, the discussions between members of the Monitoring Committee revealed levels of information about and understanding of the concept that varied greatly from member to member.

Transparency and reproducibility

The possibility of reproducing the calculations was tested successfully for France. However, this phase of the examination revealed some deficiencies in the area of transparency or limits inherent to the data that may have significant consequences for quantifying

[16] *Boutaud, personal communication.*

of the footprint. This is the case for the—somewhat obscure—origin of the conversion constants and the necessity for clarification of the notion of embodied energy.

Interpretation of developments in the footprint

The analysis over time conducted by the SOeS showed that the EF, of which the level for France changed little over the 1975-2005 period, was subject to short-term erratic variations relating more to contextual changes than to structural changes in behaviour. Furthermore, with the exception of one or two years, changes in CO_2 emissions contribute on average 60 per cent to global variations in the EF. Use of the EF to evaluate public policies aiming to foster sustainable development therefore appears to be problematic.

Points of agreement

The members of the Monitoring Committee observe that the methodology used to develop the indicator has evolved in favour of an improvement in robustness of the calculations. They consider, overall, that the EF constitutes a powerful communication tool to raise awareness of more environmentally friendly consumer behaviour in the different sectors of society.
Furthermore, they are of the opinion that the indicator responds to a concern to understand sustainable development in a global and inter-dependent framework. However, a consensus also exists, including amongst the designers, on the notion that the EF cannot alone reflect all of the economic, social and environmental issues surrounding sustainable development.

Points of disagreement

For some, such as WWF-France and GFN, the EF makes it possible to indicate a global overshoot of the planet's natural capacities, i.e. that the current form of development is unsustainable in the long term.
For others, in the majority, the deficit arises mainly from excess CO_2 emissions, leading to their preference for a carbon footprint deemed simpler and more rigorous.

Annexes

Response from Global Footprint Network

SOeS provides thorough research to test the transparency and reproducibility of the 2008 edition of Global Footprint Network's National Footprint Accounts. This is to be welcomed, since reviews and testing are essential for scientific progress. The extensive review shows that indeed there is a high degree of transparency and reproducibility.

This is a significant finding, since Global Footprint Network's key offering is advancing a scientific inquiry on what might turn out to become the most significant research question of the 21st century: *How much biocapacity is occupied by human activities?*

The Ecological Footprint is an accounting system for tracking human demand on ecological services. It attempts to answer one particular scientific research question, not all aspects of sustainability, nor even all environmental concerns. It analyses the human predicament from this distinct angle, motivated by the assumption that Earth's regenerative capacity might be the limiting factor for the human economy if human demand continues to overuse what the biosphere can renew.

Are the Footprint figures presented in the 2008 edition perfect? No. Will they ever be perfect? Possibly not, but they are getting better over time. This is the nature of any scientific inquiry, including reviews like the one to which we are responding. But it will take more than reviews to perfect the method and its results. This will require serious research collaborations, because the scope of the research is large, exceeding in complexity and difficulty even GDP assessments. Footprint accounts not only capture human demand in much detail, but also track nature's "income" – biocapacity.

As GDP assessments have never given the perfect answer to their particular research question, Footprint accounting will have limitations as well. But the question is: Is the research question underlying the Footprint and biocapacity assessment essential to sustainable development efforts or merely tangential? Are other indicators covering this research question more adequately?

If the research question is deemed significant, then the question becomes how well the question has to be answered in order to make results useful for policy debates. Perfection is not achievable – with such expectations, GDP would never have been introduced. Therefore, an aspect this research may have wanted to discuss is: does the Footprint accounting method do less justice to its research question than GDP does to the GDP research question? A useful comparison would be to analyze the extent to which the Footprint method is any more speculative in answering its research question than GDP is in answering the GDP research question?

In essence, SOeS's report shows that the current Footprint method is transparent and reproducible. Yes, many aspects can and should be improved. This has been pointed out by Global Footprint Network research (Kitzes et al. 2007, 2009) as well as many national and international reviews Global Footprint Network has encouraged (Eurostat, DG Environment, Switzerland, Belgium, Luxembourg, Germany, Ireland, United Arab Emirates, and others).

What this research has made clear is that Global Footprint Network's research agenda is consistent with SOeS's technical assessment. Yet, Global Footprint Network also advocates that nations get involved in the research as well, rather than just doing reviews. There is too much at stake to leave this research to just one research organization. Global Footprint Network's ambition is therefore to bring nations together to improve the method consistently and collectively, with significantly more research muscle.

Global Footprint Network would have hoped that SOeS would have built more strongly on the insights of President Sarkozy's "Commission on the Measurement of Economic Performance and Social Progress" (also known as the "Stiglitz Commission") released its first report on September 14, 2009.17 The commission's key findings are that:

GDP is no longer adequate as a prime measure for managing economies. We need more sophisticated tools for tracking economic performance, quality of life, and environmental sustainability.

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[17] *"Stiglitz Report" (Report of the commission on the measurement of economic performance and social progress")* http://www.stiglitz-sen-fitoussi.fr/en/index.htm.

Economic performance, quality of life, and environmental sustainability need to be measured separately in order to understand potential trade-offs between them, so the trade-offs can be overcome.

1. Particularly for environmental sustainability, we need physical indicators beyond monetary measures, since monetary measures are weak descriptors of environmental and resource realities, particularly for mid to longer-term horizons.

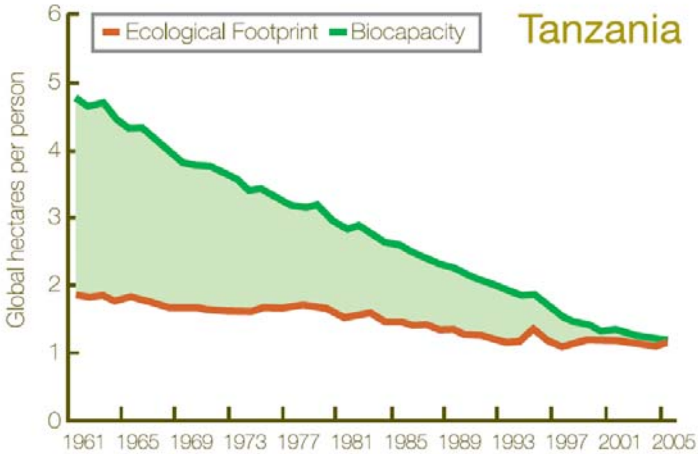
2. The two primary physical measures for environmental sustainability are

    a. the Ecological Footprint, and
    b. one of the Footprint's most significant components, the carbon Footprint.

While the Stiglitz Commission suggested focusing on the carbon Footprint, and the SOeS seems to insinuate as well that focusing on carbon accounting may be sufficient, Global Footprint Network argues that a "carbon plus" view is necessary in order to understand the significance of current environmental trends.18 The Ecological Footprint fully and wholly contains the carbon Footprint, and takes a comprehensive, more effective approach by tracking a full palette of human demands on the biosphere's regenerative capacity. It can also compare this demand against availability of biocapacity.

With a carbon analysis alone, trends as shown in the example of Tanzania (in Figure 1) would not be visible to the assessment – the carbon Footprint of Tanzania in 2005, for example, was less than 8 percent of the overall Footprint (or about the thickness of the red line in Figure 1).

Figure 1: Tanzania's per-person Footprint and biocapacity since 1961



Source : GFN.

Tanzania's Footprint represents the biocapacity needed, on average to provide for the average consumption of a Tanzanian resident. The biocapacity is the productive area available within Tanzania. The green surface between the lines shows the shrinking ecological remainder of Tanzania. Once the lines cross, the remainder becomes an ecological deficit. Ecological deficits can be compensated by overusing local biocapacity or by using biocapacity from abroad, for instance through net-import.

Obviously, it is up to Europe to choose the extent to which the Footprint should be part of its core sustainable development indicators. If these indicators should truly address sustainable development, then they need to have the ability to determine, whether a nation or the world has breached ecological limits or not. The ones proposed so far have little if anything to reveal about the topic. If society considers that ecological limits are irrelevant, then we should be honest and focus on "accelerated development" rather than deluding the public in calling something "sustainable development" which lacks any meaningful interpretation of the concept.

[18] *The Global Footprint Network response is at*
http://www.footprintnetwork.org/en/index.php/newsletter/bv/commission_urges_gdp_rethink_new_footprint_standards_released

In summary, the questions any nation needs to consider are simple. Is your nation better off not knowing:
a) the amount of biocapacity it has, and how much it uses?
b) the amount of biocapacity humanity uses compared to what the planet can regenerate?
c) trends related to biocapacity and resource use?
If this information isn't absolutely central to the sustainability challenge, what is?

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Members of the Monitoring Committee

- Ms Isabelle Blanc, Mines ParisTech
- Mr Aurélien Boutaud, association Terr-e-toires
- Mr Martin Bortzmeyer, CGDD - MEEDDM
- Mr Bernard Cressens, Director of Conservation Programmes, WWF-France
- Mr Willy de Backer, Director for Europe, Global Footprint Network
- Mr Louis de Gimel, Insee
- Ms Natacha Gondran, École nationale supérieure des Mines de Saint-Étienne
- Ms Nicole Jensen, CGDD - MEEDDM
- Mr Marc-Antoine Kleinpeter, CGDD - MEEDDM
- Mr Philippe Le Clézio, rapporteur for the Commission sur les indicateurs de développement durable et l'empreinte écologique pour le CESE
- Mr Valéry Lemaître, CGDD - MEEDDM
- Mr Vincent Marcus, Insee
- Ms Thanh Nghiem, Institut Angenius
- Ms Simone Paul-Collinet, CGDD - MEEDDM
- Mr Frédéric-Paul Piguet, Institut des politiques territoriales et environnement humain, université de Lausanne (Suisse)
- Mr Pascal Rouet, CESE
- Ms Carla Saglietti, CESE
- Mr Thierry Thouvenot, Consultant for WWF
- Mr André Vanoli, Chairman of Association de Comptabilité nationale
- Ms Dominique Veuillet, Ademe
- Mr Mathis Wackernagel, CEO, Global Footprint Network
- Ms Natacha Zuinen, bureau fédéral du Plan de Belgique, Task Force Développement durable

Commissariat général au développement durable
Service de l'observation et des statistiques
Tour Voltaire
92055 La Défense cedex
Tél : (33/0) 1 40 81 13 15 – Fax : (33/0) 1 40 81 13 30
Email : cgdd-soes-orleans@developpement-durable.gouv.fr

This publication is available on : http://www.statistiques.developpement-durable.gouv.fr

An expert examination of the ecological footprint

The ecological footprint concept, developed in the early 1990s, corresponds to the land area required to provide resources to a given population and to absorb its waste.

The expert examination conducted by the Commissariat général au Développement durable – Service de l'observation et des statistiques *(CGDD–SOeS – Department of the Commissioner-General for Sustainable Development – Department for Observation and Statistics) of France's* Ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer *(MEEDDM – ministry for Ecology, Energy, Sustainable Development and the Sea) aims to provide elements arguing either in favour of adopting the footprint or rejecting it, on the basis of scientific criteria.*

With the support of a Monitoring Committee, the SOeS has carried out standard quantification of the footprint based on calculation algorithms and data provided by the Global Footprint Network (GFN). The aim was to evaluate the robustness of the footprint methodology on the basis of international evaluation criteria. To do this, the SOeS identified the data sources and conversion constants used by the GFN and then analysed the calculation chain so as to compare results.

The SOeS also carried out a brief statistical analysis to situate the ecological footprint at the European level and against other indicators.

The conclusions of the study are presented in issue No. 16 of the Études & documents *collection.*

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